Structural Geology and Tectonics GEO3-1307

Date: Friday April 19th 2013
Time: 08.30-11.00 hr. (2.5 hr)
Place: EDUC Beta

Please read the complete exam before starting. Ask any language related questions. Then, answer all 3 questions (they are worth 3.3 points each). *Always explain how you came to your answer.* Be creative and good luck!

Question 1: Quantification of strain

A happy structural geologist has investigated a folded marine limestone layer in the central Apennines, Italy (Fig. 1). The fold axis was found to be horizontal. The limestone contains many deformed fossils known to initially have symmetrical shapes. When studied in North-South sections through the outcrop, the fossils look undeformed. The limestone layer is full of small scale veins that seem not to extend outside the layer. The veins indicate a 11% volume change during folding.

a) Accurately determine the strain ratio of the deformed fossils for both limbs of the fold. Also determine the orientation of the axes of the strain ellipses and put these on Fig. 1a. HAND-IN the figure after having finished the exam.

b) What can you learn from the analysis of the outcrop with respect to the fold mechanism? What does it tell you about the shape and orientation of the small-scale veins?

c) Quantify the strain of the limestone in 3 dimensions by giving values for the three principal strains. Use a suitable and fully-annotated Flinn diagram to show which type of strain is applicable.

d) The tensor that is believed to describe the deformation of the western limb of the folded limestone is given below. The *base of the limestone* is used as reference line (so *not* the horizontal!). Make a full analysis of the tensor in order to check if your results of 1a) are consistent with the predictions of the tensor.

$$F_{ij} = \begin{pmatrix} 1 & -1.1 \\ 0.1 & 1 \end{pmatrix}$$

Question 2: Faults and structural styles

Fig. 2 (see end) shows a cross-section through a complex geological structure. Vertical scale is in kilometers, but note that the vertical and the horizontal scale are not the same.

a) Make a clear list of *observations* for the cross-section. Use numbers, colors or other annotations to relate your observations to specific parts of the section. HAND-IN the figure after having finished the exam.

b) Give an *interpretation* of the geological history of the part of the crust shown in the section, consistent with your observations (part a). Present this interpretation in a framework of 'structural styles'.

Sediment samples from the top one kilometer of the section have been tested in a famous deformation laboratory, resulting in a value for the "cohesion" of the sediment of 10 MPa, and a coefficient of internal friction (μ) of 0.25 (i.e. the slope of the failure envelope in a Mohr diagram).

c) Does Fault A fit with the laboratory results? Explain your answer.

d) Explain what a compaction band is. What information do you need to predict if compaction bands can be expected in the sediments of the cross-section? (you may want to use a schematic Mohr diagram to illustrate your answer)

Question 3: Deformation processes in the elastic/brittle and ductile fields

Fig. 3 (next page) shows a conceptual model for a deformed part of the crust. Basic information on the history of structures such as that of Fig. 3 can be obtained from analysis of thin sections of metamorphic rocks including porphyroblasts.

a) Describe the main elements of the model (observations!) and speculate about the structural style or tectonic setting (interpretation).

b) The model shows an upper crustal brittle layer and a deeper ductile layer. Give a very brief account of the main mechanisms of brittle and ductile deformation and their characteristic microstructures.

c) How does an analysis of porphyroblasts in in deformed rocks help reconstruction of the evolution of rocks such as those included in the model of Fig. 3? Use the microstructure of Fig. 4 (below) to illustrate your answer.

d) Define a research question that could be the basis of a scientific project aimed to better understand the structure of Fig. 3. Don't make the question too broad (i.e. too vague) and think ahead: what could you do to answer this research question?

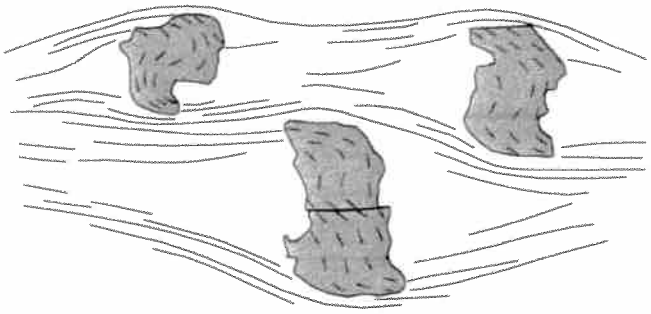

Fig. 4 (with question 3)